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A BID RENT APPROACH TO HOUSING DEMAND

William C. Wheaton

Number 135 July, 1974

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Over the last decade there has been an increased realization that aggregate, 1-dimensional models of housing demand are of little use to policy makers in assessing alternative strategies for aleviating America's often voiced housing "problems." This has been accompanied by an awareness that housing "demand" really represents a complicated and interdependent choice situation along many dimensions including location. Thus the problems of urban travel congestion, open space and land use are all products of this greater conception of housing "demand." In response to these views, economists have recently developed a new approach to modeling housing and locational choice. While this methodology implicitly recognizes the "hedonic" character of the housing choice situation, it does not utilize or take advantage of the "hedonic" property. Within this context, the aims of this paper are three-fold.

First we will review the basic approach used by several recent urban micro-models of housing demand. Second, we will develop a "dual" approach to housing choice, based on Alonso's theory of bid rents. In this approach, consumers do not select optimum points on the hedonic surface given a price gradient. Rather they offer a price gradent given a level of indifference. We will provide a much-needed formal proof that these two approaches achieve identical equilibrium solutions. The advantages of the bid approach are several, but perhaps most importantly, it provides a new basis for direct empirical estimates of consumer utility functions. The third aim of the paper is to utilize this methodology, with San Francisco Bay Area home interview data, to estimate consumer preferences for a variety of housing and locational attributes. Our results are extremely promising -

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not only in illuminating differences in housing preferences among consumers, but also because they suggest the bid rent approach is indeed a feasible way of simulating urban housing markets.

II.

Urban housing is usually considered a good in itself primarily because there exists a single housing market in which consumers trade freely. Of course, it is well recognized that housing is anything but a uniform, homogenous commodity. In reality it is composed of many "subgoods" or attributes for which separate markets do not exist. It is these attributes which provide consumers with "utility." These characteristics make housing a "hedonic" good, as defined by Lancaster (1966) and Rosen (1974).

Recent attempts to apply the hedonic approach to housing have adapted it to the inherently discrete character of the housing stock in the short run. An appropriate title for this version has been coined by Quigley (1974) as a theory of "Polytomous Choice." The theory discussed below is the implicit foundation forseveral of these recent housing demand models.

The housing market under consideration is conceived of having n persons (i) who are buyers and m homogeneous zones of housing (j). Naturally, if more detail is needed, m can represent unique units. Housing is characterized by a vector of attributes X, which presumably includes locational characteristics (time to work, neighborhood and municipal amenities) as well as unit quality and quantity. To keep the discussion as simple as possible, consumer utility is written in a "partially indirect" form - depending on the vector of housing attributes X and all non-locational expenditure M.

$$u_i = u_i(X, M) \qquad i = 1,n \qquad (1)$$

Individual i's income (Y_i) is partitioned into travel expenditure (T), the rent associated with the housing package X (R), and of course M.

$$Y_i = M + T + R \tag{2}$$

Inserting the budget constraint into the utility function, and attaching the appropriate subscripts, we have the expression for the level of utility that each consumer would enjoy were he to live in each unit or package.

$$U_{ij} = U_i(X_j, Y_i - R_j - T_j) \tag{3}$$

Given a pattern of rents (R_j, j=1,m), each consumer selects that unit where his utility is at a maximum, and of course this choice need not be unique. The "demand" for each unit j is then the (integer) number of consumers who have selected that package as their utility-maximizing one.*

The basic equilibrium problem is to find a set of rents (R_j*, j=1,m) such that the "demand" for each unit exactly equals the number of units in that zone (or 1 when units are uniquely defined). An equilibrium can be achieved if m either equals or exceeds n. In either case we need a numeraire to establish actual (as opposed to relative) rent levels. When the number of units exceeds the number of persons, this is handled by making vacant units rent for an exogeneous opportunity cost. The case of a perfect match between buyers and units in more problematic, and is best handled by simply adding an extra unit. Of course, all of this is just the demand side. As equilibrium prices are established, presumably suppliers are adding to or adjusting the stock characteristics (X_j, j=1,m).

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*There is some question as to how to handle ties. The individual's "demand" can be "partitioned" among his several utility-maximizing units or arbitrarily assigned to only one.

This general theory of "Polytomous" choice has been the basis of much recent work in housing demand. Sweeney (1972) has developed a very thorough theory of discrete choice, but only under the assumption that all consumers possess identical ordinal rankings over X. Although this is quite unrealistic, it does allow aggregation of the X vector into a "quality" sector, and as a consequence Sweeney is able to prove some strong theorems related to demand effects and the existence of equilibria. Deleeuw (1971) has developed a model around this theory, using a Cobb-Douglas utility function. Like Sweeney, Deleeuw aggregates the X vector over unit attributes, although travel time and community amenities are kept separate. Lastly, Kain et. al. (1971) and Quigley (1974) have developed choice models for use in the N.B.E.R. simulation model. Both use the X vector in dissaggregated form, and thus provide some insight about consumer preferences for housing attributes. Their models, however, use a two-stage choice procedure: first selecting a utility-maximizing unit, then a cost-minimizing location.

III

Alonso (1960, 1964) was the first writer to realize that the hedonic character of goods made possible a sort of "dual" approach to consumer demand. Alonso never discussed housing per se, only the long run problem of allocating land over space. "Location" was his hedonic good which had two attributes - density and distance to an employment center. Several years later, Britton Harris (1965) suggested that the Alonso approach could also be used to tackle the problem of consumer choice among a fixed, heterogeneous housing stock in the short run. With some changes, the discussion below is based on the Harris suggestion.

The Alonso-Harris approach looks at the market from the owner or seller's point of view. Rather than have consumers select units (and therefore location) based on an existing set of market rents, landowners select consumers for occupancy of their units. They have this right since space (and other housing attributes as well) make each owner a monopolist over a unique commodity (Ricardo, 1817). Consumer's must bribe or offer "bid rents" to owners for the privilege of occupancy (or ownership). Competition among atomistic individuals insures that each unit goes only to that consumer offering the highest or maximum bid rent.

Consider the same choice problem as in section II, with n persons (i) and m location/units (j). Consumer i's bid rent for location j (R_{ij}) is defined as that payment to the owner of j that would leave him at a fixed level of utility (U_i^o) - given the attributes of j (X_j). Using the utility function (1) and budget constraint (2), it is the solution to (4) for R_{ij}.

$$U_i^o = U_i(X_j, Y_i - R_{ij} - T_j) \tag{4}$$

Assuming the solution can be analytically identified (by a function U_i^{-1}), we may write:

$$R_{ij} = Y_i - T_j - U_i^{-1}(X_j, U_i^o) \tag{5}$$

The level of indifference U_i^o plays an important role. Since non-locational expenditure M has positive marginal utility it follows that $\partial R_{ij}/\partial U_i^o < 0$. Lower levels of utility allow people to bid more and hence presumably acquire the housing they need in the market.

The equilibrium problem is now to find a set of U_i^* (i=1,n) so that each unit/location j goes to the highest bidder and so that each consumer has the maximum bid over one and only one unit. The outer envelope of bid rents, at equilibrium utility levels, is the market rent surface. As yet there has not been a proof that an equilibrium set of utility levels always exists for "regularly" defined preferences and housing stock characteristics. Numerical problems, however, always exhibit quick convergence if utilities are adjusted on the basis of how many units each consumer presently "commands." Starting from some point, consumer i's utility is raised if he has the highest bid over more than one unit and lowered if he is highest over none. Of course we can still not determine the absolute rent level without a numeraire and so all bids must exceed some "opportunity bid" which becomes the price of vacant units. The task of allocating persons to units, and adjusting utility levels can be formulated as a linear programming problem to maximize rents (Wheaton, 1974). Alternatively, simple algorithms, following the logic above seem quite suitable for small problems.

In summary then, the classical consumer approach to hedonic goods takes rents and allows consumers to decide on location according to utility maximization. Equilibrium is then achieved by adjusting these rents. The bid approach takes utility levels and allows owners to decide on location so as to maximize rents. Equilibrium is obtained by adjusting utility levels.

IV.

One of the main issues with the bid rent methodology has always been whether it achieves the same equilibrium solution as the classical consumer approach. Intuitively, one suspects that there is some sort of dual relationahip between utility and rent maximization which would insure that the location and rent patterns derived by each are identical. In this section, we prove that the allocation pattern, and outer-envelope rent structure achieved with the bid rent approach, is indeed an equilibrium solution to consumer utility maximization.

Consider the bid rent model of section IV. Assume that there are enough units for all households to find a location and let k_i be the index of that location household i locates in at equilibrium. By definition of a bid rent equilibrium:

$$R_{ik_i} > R_{jk_i} \qquad \begin{array}{l} j=1,n \quad j \neq i \\ \text{over all } i=1,n. \end{array} \tag{6}$$

The outer-envelope, equilibrium rent surface is therefore R_{ik_i} $(i=1,n)$. We seek to prove that using this rent profile, utility maximizing consumers (as discussed in section II) would select the exact same location pattern (the index k_i, $i=1,n$).

Proposition: Given the equilibrium rent profile R_{ik_i} and location pattern $k_i (i=1,n)$, obeying condition (6), then

$$U_i(X_{k_i}, Y_i - T_{k_i} - R_{ik_i}) > U_i(X_{k_j}, Y_i - T_{k_j} - R_{jk_j})$$

$$\begin{array}{l} j=1,n \quad j \neq i \\ \text{all } i=1,n \end{array}$$

Proof: $$U_i(X_{k_i}, Y_i - T_{k_i} - R_{ik_i}) = U_i(X_{k_j}, Y_i - T_{k_j} - R_{ik_j})$$

since the bid rent surface over packages X_{k_i} and X_{k_j} (R_{ik_i}, R_{ik_j}) by definition involves constant utility.

$$U_i(X_{k_j}, Y_i - T_{k_j} - R_{ik_j}) > U_i(X_{k_j}, Y_i - T_{k_j} - R_{jk_j})$$

because $R_{jk_j} > R_{ik_j}$ by (6), and $\frac{\partial u}{\partial R} = \frac{-\partial u}{\partial M} < 0$.

Thus for each and every consumer i, at his equilibrium location k_i and bid rent R_{ik_i}:

$$U_i(X_{k_i}, Y_i - T_{k_i} - R_{ik_i}) > U_i(X_{k_j}, Y_i - T_{k_j} - R_{jk_j})$$

or his utility exceeds that he would obtain were he to locate at any other location k_j, paying the equilibrium (outer envolope) bid rent there R_{jk_j}. In short, with the equilibrium price profile from the bid rent approach, utility maximizing consumers would select the bid rent location pattern.

Q.E.D.

Since the two approaches are really the same, one might legitimately ask for a criteria to choose among them. We can offer two that seem to favor the bid rent approach. In the first place, real world models must aggregate individuals into strata and units into zones. Usually this involves considerably more zones than strata (m > n). In large measure this has to do with inadequacies in urban data basis, but it also reflects the necessity for small areal detail to achieve any degree of homogeneity in the stock. In trying to obtain equilibria, it is desirable to deal with systems having as few parameters as possible. Since m is frequently many times n, it would appear to be much easier to adjust n utility levels in a bid rent model rather than m prices in the consumer approach.

The second advantage of the bid rent model is that it provides an easy method for directly estimating the parameters of consumer utility functions. It avoids the problem of trying to identify "demand" functions for a heterogenous hedonic good by utilizing an important feature of equilibrium solutions in the housing market. This estimating methodology is discussed below.

V

The estimation procedure used with bid rent theory is based on two critical assumptions. The first of these is that individuals with similar demographic characteristics do indeed have similar utility functions. Variables such as position-in-life-cycle, family size, race, occupational and educational background are presumed to account for much of the variation in tastes or preferences. The second assumption is that the housing market at any point in time is at a short run equilibrium. This requires that individuals with similar characteristics (who presumably have the same utility function) will in fact be at a common level of utility. These issues deserve some further discussion.

Within metropolitan housing markets, holding demographic variables such as those above constant, still leaves a great deal of variation in the consumption of housing packages. Controlling for income and place of work reduces this substantially, but a significant residual usually remains. Were housing a normal good, for which utility maximization leads to a unique solution, we might conclude that this residual variation implies preferences and income have not been kept truly constant. The hedonic character of housing, however suggests another explanation.

Because the housing stock evolves gradually overtime, it is always extremely diverse and heterogeneous. At any one point in time, if the market is to achieve equilibrium, it is inevitable that similar individuals locate in different units. This is a natural phenomena with hedonic goods, and simply requires that rents adjust to compensate households for differences in their housing.

The issue of whether the market is truly at such an exchange equilibrium is more troublesome. One can easily point to factors such as frictional moving costs and imperfect information which indicate the contrary. Our estimation procedure, however, only assumes that households with the same preferences and income are approximately at a fixed utility level. Error or variation in this level (due to frictional factors) serves as one basis for the introduction of a stochastic term. The other major source of error in the estimating equations is omitted or innaccurate data.

Within this framework, the bid rent equation (5) can be directly estimated for each household strata, once a utility function is specified. In this study, two functions were tried - the first being the logarithmic or Cobb-Douglas form (6), which is estimated in the form (7).

$$U = \sum_i \alpha_i \operatorname{Log} X_i + \operatorname{Log} M + \varepsilon \qquad (6)$$

$$M = Y - R - T$$

$$\operatorname{Log} (Y - R - T) = U - \sum_i \alpha_i \operatorname{Log} X_i - \varepsilon \qquad (7)$$

The level of utility for each stratum (U) is estimated as the regression constant. A monotonic transformation of the utility function yields the same estimating equation and hence parameters except for the term U which absorbs this change. Of course this function has a number of severe restrictions - namely homotheticity with equal (and unitary) elasticities of substitution between every pair of attributes. The most simple function which overcomes all of these restrictions is a generalized version of the C.E.S. function (8), which is estimated in the form (9)

$$U = -\sum_i \beta_i X_i^{-\alpha_i} - (M + \varepsilon)^{-\alpha_o} \qquad (8)$$

$$M = Y - R - T$$

$$Y - R - T = (-U - \sum_i \beta_i X_i^{-\alpha_i})^{-1/\alpha_o} - \varepsilon \qquad (9)$$

This function is not homothetic, does not have constant nor equal elasticities of substitution, and has indifference curves which asymptote minimum consumption levels (a reasonable requirement for housing attributes). Of course it is quite non-linear in its parameters and hence requires more complicated estimating procedures.

In the Cobb-Douglas equation (6), the stochastic term (ε)is added to U in keeping with the assumption that error results from the market not being quite at equilibrium. In the C.E.S. estimating equation (8), the error is associated with the measurement of Y, R and T. These assumptions were made to keep the liklihood function as simple as possible. A further assumption, that ε is normally and independently distributed, allows us to use ordinary least squares for both models. There is some question as to whether all these stochastic assumptions are fully justified, but we felt it best to take the most simple approach first. Future work will investigate the possibility of non-additive terms with non-spherical distributions.

Minimizing the sum of squared residuals around equation (9) is a non-linear programing problem, for which we used an algorithm due to Fletcher and Powell (1970). Their method is a modified steepest descent, using a gradient that is rotated with an approximation to the inverted Hessian matrix. The procedure was remarkable quick given the size of the problem (2 parameters for each housing attribute), although it sometimes would stall and require re-starting. As long as stalling doesn't happen, it automatically produces the matrix of asymptotic variances and covariances at the minimum solution.

A typical estimation for each stratum required 150 iterations, using roughly $8.00 of 360/70 computer time.

VI

The data for this study came from a home interview survey, done in the San Francisco Bay area during 1965. The data on housing included lot size (land) number of rooms and structure age. From census tapes, we acquired estimates of the distribution of income in both the respondents census tract and community. These variables were used as a proxy for community service benefits and neighborhood externalities. At the community level, median income proved a good predictor, but at the census tract level, the distribution of income by actual categories had a great deal more explanatory power than simply the median. Indications were that income categories may have been a partial proxy for other race and ethnic dimensions of neighborhood externalities. Travel information included the respondent's times and costs to work, as well as a measure of each census tract's proximity to shopping and industry in general.

A recurrent problem in such studies is how to handle the question of tenure. In our case, we decided that the difference between renting and owning often represented an implicit choice for certain types of housing as well as desire for specific financing arrangements. To obtain more comprehensive preference surfaces, we combined tenure categories. Rent payments were directly available, while property value was converted to annualized rent using representative interest rates, local taxes and maintenance costs.

Demographic data allowed us to stratify households on the basis of life-cycle, income, occupation and race. Life cycle was a variable joining age-of-head and family size into the eight categories shown in Table 1.

Table 1: Life Cycle Categories

Category	Age	Size
1	under 31	under 4
2	under 31	4 over
3	31-55	under 3
4	31-55	3-4
5	31-55	5-6
6	31-55	7 over
7	56 over	under 3
8	56 over	3 over

Combined household income was split into 4 categories: \$5,000 - \$10,000, \$10,000 - 15,000, \$15,000 - \$25,000, and over \$25,000. It must be remembered that income here represents the effect of economic background and status on tastes. Income enters continuously as purchasing power in the bid rent equation. Lastly, occupation was defined by white and blue collar, and non-whites were separately identified. The resulting 128 strata are identified by a 4 digit number. The first digit is race, the second life cycle category, the third income grouping, and the fourth race.

A final problem of household stratification involves the assumption that households within these cells are truly at an equilibrium fixed level of utility. The two most overt sources of utility variation are differences in place of work, and household purchasing power. Different employment centers will give rise to different travel expenditures, even though land rents are the same. A competitive labor market should capitalize these advantages into different wage rates but experience suggests real utility differences may still be allowed by the market. To overcome this, each strata was restricted to those working in the greater San Francisco C.B.D. (slightly less than one half of the sample). Variation of income within strata was handled by making the level of utility in (7) and (9) depend monotonically on reported income. The parameters of this function would be estimated along with the rest.

With all of this stratification, our sample sizes became extremely thin. The linear equation had 11 parameters while the non-linear had 21. A rule of thumb suggested we would need at least 40 observations in each strata for minimally reliable estimates. This criteria unfortunately eliminated all non-white strata as well as white blue-collar households. The only way to recapture these observations would involve making an already coarse stratification system even more so. Feeling that preserving homogeniety within strata was essential to the estimation process, we keep the present categories and selected seven representative strata. These household groups (Table 2) do provide an important comparison of differences in life cycle, household size and income.

Table 2: Estimated Household Strata

Code	Age	Size	Income	Sample Size
1421	31-55	3-4	5000-10000	106
1431	31-55	3-4	10000-15000	144
1441	31-55	3-4	15000-25000	100
1451	31-55	3-4	25000+	45
1121	- 31	1-3	5000-10000	120
1721	56 +	1-2	5000-10000	79
1531	31-55	5-6	10000-15000	69

The estimated parameters (with T values in parenthesis) are found in Appendices A and B. Of course for the non-linear estimates (Appendix B), the T values have only asymptotic properties. The non-linear results show consistently higher R^2 values, but the comparison is not really meaningful because the dependent variable in the linear case is the log of that used in the non-linear equation. On a priori grounds, however, the non-linear equation should achieve a better "fit" than the linear, for the latter is simply a limiting case of the former.

The significance of parameters is clear from the T values in the linear case, but the non-linear results are more complicated. The path of the estimating algorithm indicated that the liklihood surface contained a flat "valley." Various combinations of parameters would produce very similar R^2 values. Some experimenting revealed that at points along this "valley," household marginal rates of substitution were essentially identical - when evaluated over the range of observations in the data. It seems safe to say, therefore, that computed marginal rates of substitution are probably more significant than the individual parameters that determine them. Both for this reason, and because it is easier to compare "preferences" by examining marginal rates of substitution instead of specific parameters, we turn to Tables 3.1, 3.2, and 4.

In each of these tables marginal rates of substitution have been computed between 6 housing attributes and non-locational expenditure (M in (6) and (8)). As was discussed in section three, these values are equivalent to the increase in annual rent payments (bid rents) each consuming group would make for an additional unit of these "commodities." Table 3.1 evaluates these MRS's at a point typical of upper middle income suburbs, while 3.2 uses variable values found usually in lower income city areas. All figures are in dollars per year, and could be converted into permanent property values with a typical capitalization coefficient.

There are a few cases of innaccurate signs. The marginal utility of rooms to stratum 1721 and average community income to strata 1121 and 1531 are all negative in the log-linear utility function. Fortunately they are insignificant statistically, and with the non-linear C.E.S. function, they achieve the appropriate positive sign, although not with great significance.Accessability is the other variable that continually exhibits the wrong sign - in both utility functions. This variable was meant to measure the proximity (a hence presumably time convenience) of shopping and service facilities. It was constructed by giving heavy weight to the presence of many such facilities in one's own area. It is possible therefore that what this index really measures is some of the negative externalities (noise, traffic, pollution) that are also associated with proximity to commerical areas. This is the best explanation we can offer for the consistent (and sometimes significant) negative marginal utility for "accessability," at least when commuting costs are held constant.

The magnitude of the MRS's and their elasticities of substitution (in the C.E.S. case) seem very reasonable when looked at across all strata. The computed value of time varies between $.05 and $1.40 per hour in the city to a range of $.20 - $2.25 in the suburbs. Greater commuting leaves less leisure, whose marginal value therefore increases. We assumed four hours of non-work-eat leisure available per day to the employed head. An increase in travel time from .5 to 1.5 hours therefore represents a

30% loss of leisure. The marginal rates of substitution increase by between 30 and 80% except for stratum 1421 where the jump is 400%. This suggests that elasticities of substitution for time are significantly less than one - when evaluated in this region.

Marginal land values, when capitalized, range from ten to twenty thousand dollars per acre in the suburbs and from sixty to two-hundred thousand dollars per acre in the city. Again these seem in the ball park. If we compute spot elasticities (for the C.E.S. function) we find that the 600% increase in land consumption between Tables 3.1 and 3.2 generates a decrease in MRS's of between 6 to 7 hundred percent. These are much closer to unity than with time.

The marginal value of a room ranges from $1500 to $5000 when capitalized and evaluated at 5 rooms. If for any strata, we add up the marginal value of the first through 6 rooms, we do usually come out with figures not that different from total housing expenditures. Again computing spot elasticities, we find that they are very close to unity.

The disutility of unit age exhibits decreasing marginal disutility. Perhaps this reflects the fact that if older units do require more maintenance, their historic or asthetic value begins to compensate for this. Alternatively there may be a decreasing cost of maintenance. Again this variable exhibits a local elasticity of substitution that is surprisingly close to 1 on the low side.

Perhaps most interesting is the amount of money people are willing to pay to live in a wealthier community. This varies from $6500 to $1500 when capitalized into value, for a community whose average income is ten rather than eight thousand dollars. This range seems considerably higher

Table 3.1: Marginal Rates of Substitution between fixed housing attributes and typical household non-locational expenditure[7] - suburban evaluation.

Strata							
Attribute	1421	1431	1441	1451	1121	1721	1531
Log Linear							
Time[1]	279	146	339	676	149	1026	302
Land[2]	1485	1275	1913	2040	255	4950	1643
Rooms[3]	42	262	218	303	96	-45	537
Age[4]	-19	-29	-50	-49	-21	-207	-26
Munic.[5]	.32	.18	.13	.06	-.03	.91	-.30
Access.[6]	-181	-232	-1266	-1030	-420	-4284	-469
Gen. C.E.S.							
Time	53	102	202	659	128	74	105
Land	915	1048	1302	1928	303	1215	1122
Rooms	105	241	216	318	48	103	201
Age	-19	-24	-42	-49	-16	-15	-23
Munic.	.26	.09	.13	.06	.03	.13	.03
Access.	-143	-173	-1476	-1051	-354	-799	365

1. Compensation for: 1 hour more travel each day (eval. at 1.5 hours).
2. Compensation for: 1 acre less land (eval. at .3 acres).
3. Compensation for: 1 room less (eval. at 7 rooms).
4. Compensation for: unit 1 year newer (eval. at 10 years old).
5. Compensation for: dollar less in average community income (eval. at 10000).
6. Compensation for: unit change in Access index (eval. at .7).
7. Evaluated at (by stratum): 4500, 8500, 14000, 36000, 4500, 4500, 8500.

Table 3.2: Marginal Rates of Substitution between fixed housing attributes and typical household non-locational expenditure[7] - city evaluation.

Strata Attribute	1421	1431	1441	1451	1121	1721	1531
Log Linear							
Time[1]	199	104	243	483	106	732	216
Land[2]	8909	7650	11480	12240	1530	29700	9860
Rooms[3]	59	367	305	424	135	63	753
Age[4]	-4	-6	-10	-10	-4	-41	-5
Munic.[5]	.40	.22	.16	.07	-.03	1.15	-.38
Access.[6]	-155	-198	-1078	-880	-358	-3650	-399
Gen. C.E.S.							
Time	12	73	142	460	79	37	75
Land	5876	6390	10310	11814	1834	7772	50807
Rooms	148	343	328	464	69	161	284
Age	-5	-5	-19	-10	-3	-3	-6
Munic.	.33	.11	.17	.07	.03	.19	.03
Access.	-122	-148	-1279	-916	-303	-702	305

1. Evaluated at .5 hours.
2. Evaluated at .05 acres.
3. Evaluated at 5 rooms.
4. Evaluated at 50 years old.
5. Evaluated at average community income = 8000.
6. Evaluated at access index = .3.
7. Expenditure evaluated by strata at: 4500, 8500, 14000, 36000, 4500, 4500, 8500.

than the reduction in tax payments that would normally accompany such a move. This suggests that our variable is capturing (as we hoped) the benefits of better services as well as the lower costs of existing services. Again, as with all variables but time, the local elasticities of substitution appear quite close to one. All of these results, however, are made without reference to specific household strata. Such differences are one of the main interests of this research.

The first comparisons to examine involve the influence of demographic or social differences, when income is held constant. Comparing strata 1421 and 1121, we see that young households, not yet in or just beginning family formation, have much higher values for time and accessability, but much lower preferences for land, rooms and municipal services (as embodied by community income). This stratum of households is not very concerned with housing in general and places more weight on other, non-locational items. Looking at older households, who have completed their families (stratum 1721 compared with 1421), we find slightly greater preferences for time and land, and noticably less concern over municipal composition. The greater value for land, and the fact that rooms are identical dispite smaller size, is keeping with the notion that older families often remain in the larger, low denisty homes that they raised children in.

The comparison of strata 1431 and 1531 examines the effect of size alone, when age or life cycle is left constant. Here, some unusual results occur. The preferences for time and age are identical but those for rooms and municipal composition are less. This goes against our notion that larger families should be more concerned over unit space and services like schools. One explanation is that larger families are forced to spend more on non-locational expenditure, leaving less for housing. The one characteristic of housing that larger families do demand more of is land. This does not come through strongly in Table 3.1 when acreage is evaluated at .3, but at .05 (Table 3.2), larger families have a much greater marginal value for land. In short, they require a minimal amount of private yard area.

The next comparison is the effect of income or economic background on preferences, when age and size are held constant (strata 1421, 1431, 1441, 1451). As can be seen from either Table 3.1 or 3.2, rising income increases the marginal valuation of all housing attributes. The exception of land and time for stratum 1421 in the log linear utility function, disappear in the C.E.S. form. With the latter virtually all relationships are monotonically increasing with income. The one consistent and highly significant reverse case - is municipal composition. As income increases, household marginal valuations for community income generally fall. The implication is that with greater wealth, the tax advantages of moving to richer communities are proportionally smaller,.and public benefits are of less concern (perhaps private services become substitutes).

Higher marginal valuations by the rich are usually explained, within economics, by the phenomena of a falling marginal utility to income (in our case non-locational expenditure). It is interesting to speculate, however, how the different income groups would compare were they given the same wealth and the background effect applied only to preferences. Table 4 examines the MRS's of each economic background (income) stratum under the assumption that all have constant real purchasing power. With a few exceptions, the marginal valuations of all housing attributes generally decline with income. Thus if wealthier people were to experience a sudden

Table 4: Marginal Rates of Substitution between fixed housing attributes and fixed non-locational expenditure[1] - suburban evaluation.

Strata / Attribute	1421	1431	1441	1451
Log Linear				
Time	527	146	206	159
Land	2805	1275	1160	481
Rooms	79	262	132	71
Age	-35	-28	-30	-11
Munic.	1.14	.17	.05	.003
Access.	-343	-232	-768	-244
Gen. C.E.S.				
Time	109	102	113	94
Land	1886	1048	731	277
Rooms	217	241	121	45
Age	-39	-24	-24	-7
Munic.	1.06	.08	.03	.002
Access.	-296	-173	-829	-151

1. For all strata, non-locational expenditure set at 8500.

loss of income, and keep their previous preference patterns, they would presumably consume less housing than someone with "low income" preferences to begin with. At least in the log linear case, all of this is tantamount to saying that not only total housing expenditure, but implicit expenditure on individual attributes is a declining fraction of income as the latter increases. All of this is consistent with an aggregate income elasticity of demand that is less than one.

VII

In several respects, these results seem quite promising. In the first place we were able to explain close to three-fourths of the cross-sectional variation in rent payments within homogeneous groupings of households. This was done with only three housing variables, and only local income as a proxy for heighborhood externalities and community services. The addition of some construction quality and style indices along with actual municipal service expenditures would doubtless improve these results even further. Secondly, several important differences in housing tastes came to light even though only 7 strata were compared. With larger samples, non-white and occupational influences on tastes, as well as further lifecycle/income effects should be uncovered. All of this suggests that further work would indeed be fruitful.

Present plans call for re-estimating housing preferences using a Pittsburgh data base. This household survey is larger in size and contains more information on housing and local services than the San Francisco data. In the Pittsburgh region, we will also attempt to use the estimated bid functions as the basis for an equilibrium forecasting model of metropolitan housing and locational choice.

Appendix A

Parameter Estimates for
Log Linear Utility Function

Strata Variable	1421	1431	1441	1451	1121	1721	1531
Travel Time	.155	.043	.0607	.047	.083	.57	.089
	(2.1)	(.9)	(1.6)	(1.4)	(1.5)	(.9)	(1.0)
Land	.099	.045	.041	.017	.017	.33	.058
	(4.7)	(3.0)	(4.0)	(3.0)	(1.9)	(2.3)	(2.2)
Rooms	.065	.216	.109	.059	.15	-.07	.443
	(.9)	(2.9)	(2.3)	(2.3)	(4.1)	(.2)	(3.3)
Unit Age	-.042	-.034	-.036	-.0138	-.047	-.46	-.031
	(1.7)	(1.8)	(2.5)	(1.6)	(3.8)	(1.9)	(1.0)
Municipal*	.71	.205	.091	.015	-.067	2.04	-.36
	(2.8)	(1.3)	(1.2)	(.5)	(.3)	(1.1)	(1.5)
N1**	1) .07	1).054	1)-.014	2).042	1)-.146	2)-5.47	1).092
	(1.1)	(1.0)	(.5)	(1.0)	(2.2)	(2.9)	(.8)
N2	2).201	2).26	3)-.15	3)-.096	3)-.167	3)1.4	3)-.085
	(1.0)	(1.5)	(2.3)	(2.8)	(1.9)	(1.5)	(.5)
N3	4).074	4).09	4).061	4).023	4).062	4)-1.41	4).186
	(1.7)	(1.7)	(2.8)	(1.3)	(2.3)	(2.3)	(3.3)
Accessabil.	-.093	-.063	-.208	-.066	-.215	-2.19	-.127
	(.8)	(.6)	(2.0)	(1.4)	(1.8)	(1.3)	(.1)
R2***	.73	.56	.79	.67	.88	.35	.64

* Ratio of municipal income to household income

** The percent of census tract in 3 of the 4 income categories:
1) 0-15000, 2) 5000-10000, 3) 10000-15000, 4) 15000 +

*** With reference to dependent variable: log (Y - R - T).

Appendix B

Parameters for Generalized C.E.S. Utility Function

Strata Variable	1421	1431	1441	1451	1121	1721	1531
Exponents*							
Time	3.338	.006	.043	.0705	.45	1.03	.0068
Land	(2.5)	(.7)	(1.2)	---	(1.4)	(1.5)	(.4)
Land	.0375	.0095	.155	.0116	.0034	.0356	1.128
	(2.8)	(3.0)	(8.0)	---	(1.2)	(1.6)	(6.0)
Rooms	.0096	.0484	.233	.125	.0928	.322	.019
	(1.4)	(3.3)	(1.6)	---	(2.2)	(1.2)	(3.0)
Age	-.242	-.015	-.513	-.0175	-.025	-.0483	-.089
	(1.4)	(2.3)	(5.0)	---	(2.1)	(.7)	(2.7)
Municipal**	.077	.026	.466	.0257	-.0053	.591	.096
	(2.6)	(1.1)	(1.6)	---	(.3)	(1.9)	(.2)
N1***	1)-.0037	1).0025	1)-.026	2).055	1)-.015	1)-.836	1)1.373
	(.8)	(2.5)	(2.0)	---	(1.9)	(4.5)	(6.0)
N2	2)-1.082	2).045	3)-.076	3)-.082	3)-.477	3)-.048	3).306
	(1.6)	(1.2)	(7.0)	---	(2.6)	(2.2)	(1.2)
N3	4).081	4).015	4)1.124	4).022	4).965	4)-.495	4).0406
	(1.8)	(2.0)	(10.0)	---	(6.0)	(3.7)	(1.8)
Accessabil.	.006	-.034	-.108	-.141	-.031	-.195	.127
	(.5)	(1.3)	(1.4)	---	(2.0)	(1.0)	(.5)
Other Goods	.136	.28	.157	.344	.1546	.0802	.154
	(4.5)	(5.0)	(5.2)	(4.8)	(5.8)	(4.9)	(7.1)

---

* : α in the utility term $-\beta x^{-\alpha}$

** : Ratio of municipal income to household income.

***: The percent of census tract in 3 of the four income categories:
1) 0-5000, 2) 5000-10000, 3) 10000-15000, 4) 15000 +.

Appendix B

(continued)

Strata Variables	1421	1431	1441	1451	1121	1721	1531
Coefficients*							
Time	.0209	.779	.0906	.0695	.0294	.0073	.506
	(1.7)	(1.2)	(4.0)	--***	(1.2)	(.7)	(3.5)
Land	.173	.592	.0155	.137	.727	.155	.001
	(6.3)	(4.0)	(3.0)	---	(1.6)	(1.3)	(2.0)
Rooms	1.94	.695	.076	.0633	.118	.0665	1.001
	(3.2)	(5.0)	(1.5)	---	(2.0)	(1.6)	(3.0)
Age	.0112	.282	.0019	.0754	.165	.0458	.0286
	(.9)	(2.0)	(1.6)	---	(2.5)	(.6)	(1.2)
Municipal	.887	.582	.017	.059	-1.339	.058	.0363
	(4.2)	(1.5)	(.9)	---	(2.0)	(1.9)	(2.0)
N1	1)-1.27	1).528	1).297	2).064	1)1.55	1)-.097	1).0012
	(2.3)	(3.0)	(2.0)	---	(3.0)	(2.2)	(2.0)
N2	2)-.005	2).329	3).359	3).13	3).148	3)-.579	3).015
	(.2)	(2.0)	(3.0)	---	(2.0)	(2.0)	(1.4)
N3	4).0409	4).497	4).0003	4).094	4).0005	4)-.0056	4).215
	(1.5)	(3.0)	(1.8)	---	(1.5)	(.2)	(2.0)
Accessabil.	-1.37	.206	.213	.0425	.698	.127	.096
	(2.3)	(1.3)	(2.0)	---	(4.0)	(1.0)	(.2)
R^{2**}	.77	.67	.82	.52	.90	.62	.73

* : β in the utility term $-\beta x^{-\alpha}$.

** : With reference to dependent variable (Y - R - T).

***: Standard errors for this strata could not be obtained due to repeated program stalling.

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